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Studies on Bacterial Leaf Spot of Bell Pepper and the Causal Organism Xanthomonas Vesicatoria (Doidge) Dowson.

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STUDIES ON BACTERIAL LEAF SPOT OF BELL PEPPER AND THE CAUSAL ORGANISM *XANTHOMONAS VESICATORIA* (DOIDGE) DOWSON

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABSTRACT

Disease-free bell pepper plants, grown in the field and in pots in soil infested the previous growing season with Xanthomonas vesicatoria, failed to develop bacterial leaf spot. These observations indicated that the organism did not over-season under the conditions tested in Louisiana.

Fifty-nine individual materials, seven antibiotics and 52 chemicals, inhibited the growth of X. vesicatoria in the laboratory when the filter paper disc-agar diffusion method was used. Four of these materials, neomycin sulfate, streptomycin sulfate, Agri-mycin 17, and cupric Omadine with lime, gave partial control of bacterial leaf spot under field conditions during the early part of the growing season. However, when environmental conditions became extremely favorable for the development of the disease, none of these materials gave significant control.

When commercial fertilizer of the analysis 8-8-8 was applied to the soil at the rates of 1,000, 2,000, 4,000, and 6,000 pounds per acre in a randomized block design, control of bacterial leaf spot was obtained with the two higher rates. However, there was a significant reduction in the yields of marketable peppers from plants grown in plots that were treated with 4,000 and 6,000 pounds per acre fertilizer.

The effect of nitrogen, phosphorus, and potassium on disease resistance was studied in a randomized block design in which 1,000 pounds per acre of commercial 8-8-8 fertilizer were applied in the row

with additional fertilizer added as side dressing. The supplementary treatments were: 1) 480 lbs/A of P, 2) 480 lbs/A of K, 3) 480 lbs/A of N, and 4) 480 lbs/A of each N, P, and K. The control had no supplementary fertilizer. The data indicated that the high rate of nitrogen was associated with the disease resistance. However, when significant control of the disease was obtained, there was also a significant reduction in the yields of marketable fruit.

In laboratory tests strains of X. vesicatoria resistant to streptomycin sulfate and cupric Omadine were isolated from zones of inhibition exhibited by these two materials.

INTRODUCTION

Bell pepper, Capsicum annuum L., is the most important of the many types of peppers grown in the United States, both in quantity produced and in economic value. It is grown in every state of the United States and over 2,500 carloads of fruit are shipped each year from about 15 states. Although only about 42,000 acres of bell peppers are grown annually, the value is estimated to be more than $22,000,000.

St. James, Tangipahoa, and Livingston Parishes are the principal bell pepper producing areas in Louisiana. According to the United States Department of Agriculture (1), an average of 2,380 acres were grown in Louisiana annually during the period 1949-1958. The sale of the peppers represented an average annual income of over $775,000 to the local farmers. However, despite the high economic value of the bell pepper industry, both the acreage and production have declined for several years. The contributing factors for this reduction have been plant diseases, insects, poor horticultural practices, and lack of irrigation facilities.

Bacterial leaf spot (Plate 1), caused by Xanthomonas vesicatoria (Doidge) Dowson (12, 13, 15, 33) occurs wherever bell peppers are grown and is probably the most serious disease of this vegetable crop. All parts of the plant above ground, including leaf, stem, and fruit are affected. Infection occurs more readily and is most serious during

continuously wet weather; however, the disease may cause considerable damage even during dry seasons. Since the bacteria invade the fruit, seed contamination is almost certain to occur during harvest of the seed. There are no reports in the literature of effective control measures for bacterial leaf spot by any spray or dust treatment of the plants.

Although numerous attempts to control the disease have been unsuccessful (14, 23, 34), some workers have indicated that partial control could be obtained with streptomycin (9, 10, 25, 40) or high rates of commercial fertilizers (11, 38, 41, 42).

The work reported in these studies was designed to determine if the bacterium was capable of over-seasoning under Louisiana field conditions, to find any economically available antibiotics or chemicals that would control bacterial leaf spot, to study the effect of high fertilizer rates on fruit production, and to ascertain the element in commercial fertilizer responsible for the resistance.

REVIEW OF LITERATURE

About 2,000 acres of bell peppers are grown commercially in certain areas of Louisiana and 40,000 acres are grown in the United States. The former provide an annual gross income of approximately three-quarters of a million dollars for the local pepper farmers (1, 28).

There are many fungal, bacterial, viral, and nonparasitic diseases of bell peppers (2, 33, 34, 35). The most common in Louisiana have been, however, bacterial spot caused by Xanthomonas vesicatoria, which also attacks tomatoes (17, 18, 37), and Cercospora leaf spot caused by Cercospora capsici Heald and Wolf.

Bacterial leaf spot was first observed in Texas in 1912 by Heald and Wolf (19). They reported that the leaves had small, elevated, brown spots and that the pustules formed were filled with bacteria; however, they made no attempt to identify the causal organism. The next report of bacterial leaf spot was by Sherbakoff in 1917 (36). He isolated a yellow-pigmented bacterium from the lesions on leaves, fruit, and stems. In inoculation experiments with four strains of the bacterium the organism produced typical lesions. This indicated that the organism isolated was definitely the cause of bacterial leaf spot. No description of the bacterium was given except that it produced a yellow pigment and grew well on nutrient agar. The disease spread rapidly in the field during continuously wet weather.

The causal organism of bacterial leaf spot which was originally isolated from tomato fruit was first described by Doidge (12, 13) in South Africa in 1920 as Bacterium vesicatorium. Gardener and Kendrick (17) also described the bacterial spot disease of tomato in 1921 in Indiana and named the causal organism Bacterium exitiosum, n. sp.; however, in 1923 they agreed with Doidge in the nomenclature of the organism (18). Higgins (21) gave a complete description of this disease on Pimento peppers and made a thorough study of the causal organism in Georgia in 1922. He questioned the identity of the organism described by Doidge because some of the physiological reactions exhibited by the organism with which he was working were different from those described by Doidge. The apparent discrepancy is understandable because recent research has shown that there are physiological strains of this organism (40).

In 1939 Dowson (15) established a new genus, Xanthomonas, for some of the plant pathogenic bacteria. The distinguishing characteristics of bacteria which belong to this genus are: a) plant pathogenic, b) gram-negative, c) rod-shaped, d) nonspore forming, e) motile by means of one polar flagellum (rarely two present) or nonmotile, f) yellow in mass on nutrient agar and on potato, on both of which abundant slimy growth is formed, and g) nonacid forming in salicin, a bitter white crystallin glucoside.

Bacterial leaf spot causes severe injury to sweet peppers but is not as serious on hot peppers. When infection occurs on young

leaves of the pepper, the spots first appear as water soaked areas and become yellow-green and slightly erumpant on the lower surface. On older leaves the spots become dark brown and are not noticeably raised. If there are many lesions they remain small and dark in color (Plate 1). Severely spotted leaves turn yellow and drop leaving the exposed fruit to sunscald. Infected seedlings may lose nearly all their foliage and some spots occasionally occur on the stem. On the fruit the spots are raised, cracked, and wart-like (14, 43).

Bacterial leaf spot of pepper has been difficult to control. All varieties of sweet peppers are susceptible to the disease. Fungicides are only partially effective as a control measure and therefore have not been used extensively. Consequently, the use of disease-free seed, seed treatment, and field sanitation have been recommended for the control of bacterial leaf spot. These measures have been inadequate for the control of the disease in seasons favorable for its development. Attempts to correlate the source of pepper plants or cropping systems with disease development usually have failed (39).

In 1922, Higgins (21) reported that seed treatment with a 1:1,000 solution of mercuric chloride for two minutes effectively controlled bacterial leaf spot. Mullin (29) also reported that seed treatment with a 1:2,000 solution of bichloride of mercury for five minutes gave excellent control of the disease. Higgins (21) found that good control was obtained when the plants were sprayed four

times with Bordeaux mixture after the disease had become established in the field.

For the past several years the application of antibiotics in agriculture has been rapidly expanding. The use of streptomycin and cycloheximide (Actidione) in the practical control of certain bacterial and fungal diseases of plants is well known, and commercial preparations of these antibiotics are on the market.

One of the earliest reports of the control of a plant disease by the use of a known antibiotic was written by Brown and Boyle (4, 5) in 1944. When "crude penicillin" was injected into galls produced by Agrobacterium tumefaciens (E. F. Sm. and Towns) Conn on Bryophyllum sp., the antibiotic stopped the growth of these tumors. No evidence for an antibiotic effect of penicillin on the pathogen in vivo was reported, and later studies indicated that the effect was largely on the host gall tissue (3, 45).

In 1952, Murneek (30) reported that he had obtained 50% control of fire blight of apples by use of streptomycin spray. The material was applied when the trees were at the 50% blossom stage. Heuberger and Paulos (20) obtained about 55% control of bacterial leaf spot based on the average number of diseased leaves in the seedbed when he used Agri-mycin (22.2% streptomycin and 2.2% terramycin) at the rate of 300 ppm streptomycin and 30 ppm terramycin.

Crossan and Krupka (10) and Krupka and Crossan (25) controlled

bacterial leaf spot significantly when they sprayed pepper plants with 250 ppm of Agri-mycin. They also stated that the antibiotic was bacteriostatic rather than bactericidal because they were able to isolate the organism from within zones of clear agar produced around streptomycin impregnated paper discs that were placed on the agar surface of plates seeded with the bacterium. When sample pieces of agar from the clear areas were seeded in broth tubes, the organism quickly resumed growth. This indicated to them that a bacteriostatic action against X. vesicatoria was obtained at 250 ppm Agri-mycin.

English and VanHalsema (16) reported the development of resistant strains of X. vesicatoria in vitro. The authors made serial transfers of the organism subjecting it to progressively greater concentrations of streptomycin and terramycin.

Thayer and Stall (40) reported that strains of X. vesicatoria isolated from tomato and pepper in Florida showed variation in colony type, physiology, and susceptibility to streptomycin. Four isolates, which differed in susceptibility in the in vitro tests, were used to measure the effectiveness of streptomycin for the control of the bacterium on field grown plants. Two isolates which were relatively susceptible to streptomycin in in vitro tests, were controlled by streptomycin sprays in the field; whereas, two isolates, which were less susceptible to streptomycin in in vitro tests, were not controlled.

Recently, several reports have implied that bacterial leaf spot could be controlled by high rates of fertilizer. Nayudu and Walker

(31, 32) have shown that high levels of nitrogen, phosphorus, and potassium reduced bacterial spot on tomato in controlled nutrient cultures.

Taylor and Dobson (39) and Taylor (38) compared the susceptibility of unfertilized field grown plants to fertilized ones which received $N-P_2O_5-K_2O$ at the rates of 75-75-75, 150-150-150, 300-300-300, 600-600-600, and 1200-1200-1200 pounds per acre. The average number of leaves lost per plant was 19.6 for unfertilized plants and 12.2, 9.6, 6.6, 1.3, and 1.4, respectively, for plots with increased rates of fertilization. They found no correlation between bacterial leaf spot development and the amounts of nitrogen, phosphoric acid, or potash in the pepper leaves.

Crossan et al. (11) obtained data which strongly indicated that the use of a complete fertilizer to give about 120 to 150 pounds of nitrogen, phosphorus, and potassium per acre would materially reduce defoliation caused by bacterial leaf spot infection. Greenhouse tests by Townsley and Crossan (41, 42) during 1960-1961 indicated that high fertility levels retarded the necrotic symptom expression and delayed the abscission of pepper leaves infected with X. vesicatoria but did not reduce the severity of leaf spotting.

MATERIALS AND METHODS

During 1961 and 1962 attempts were made to determine whether or not the bacterium, X. vesicatoria, was capable of over-seasoning under field conditions in Louisiana. Seed obtained from disease-free plants grown the previous year in St. James Parish were planted in a coldframe isolated from all other pepper plants. Flats filled with a 2-1-1 mixture of soil, sand, and peat moss were placed in the cold-frame and then fumigated with methyl bromide (Dow MC-2) in order to avoid contamination. In 1962, as a check, 250 plants grown in this manner were set 30 miles from any known commercial peppers at the Idlewild Experiment Station near Clinton, Louisiana, to insure disease-free peppers.

In 1961, approximately 9,000 disease-free plants were taken to a location near Hester, Louisiana, where they were set in a cut of land on which bell peppers infected with bacterial leaf spot had been grown the previous year. Thirteen hundred plants were also set in a field at Ponchatoula, Louisiana, in soil in which infected peppers had been grown in 1959. Approximately 600 plants in three rows were set at the Louisiana State University Experiment Station, Perkins Road Farm, Baton Rouge, where diseased plants were grown the previous year. As a control, a row of 150 plants was set approximately 200 yards away in soil in which there was no record of peppers having been grown previously.

In 1962, 500 disease-free plants were taken to each of five locations A, B, C, D, and E in St. James Parish. The plants at locations A, B, C, and D were set in areas isolated from other pepper plants and in soil which had produced peppers infected with bacterial leaf spot the previous year. At location E, 500 pepper plants were set adjacent to a commercial pepper planting in an area in which bacterial leaf spot had not appeared during the preceding year.

On July 1, 1960, four five-gallon glazed crocks were filled with sterilized greenhouse soil and infested with pepper leaves infected with bacterial leaf spot. These crocks were placed in the greenhouse and beans were kept growing in the soil until December. On December 14, January 17, February 16, March 6, April 28, and May 30, two flats were filled with soil taken from these crocks and disease-free pepper seed were planted in them. These flats were placed outside where the soil could be splashed on the leaves by the rain or by water from a hose. On January 26, February 16, April 10, May 19, and June 22 attempts were made to isolate the bacterium in a total of 500 dilution plates according to the method described by Johnson et al. (24).

In July 1961, ten five-gallon crocks were filled with soil which was mixed with plants severely infected with bacterial leaf spot from the Perkins Road Farm. In addition to the infected plants, a culture of X. vesicatoria was added to each crock. These crocks were then placed in the author's backyard. On April 3, 1962 five disease-free

pepper plants were transplanted to each of eight crocks. Three of the plants in each crock were removed in June and the two remaining plants were maintained until September, 1962. During this time, the plants were watered so that the soil was splashed on the leaves. In addition, approximately every two weeks a muddy slurry of the soil was spread over the leaves of the plants. One hundred soil dilution plates were made from this soil on December 20, February 1, and March 26, in attempts to isolate the organism.

During 1961, a preliminary field trial was conducted with four chemicals (Table I) which were reported by their producers to possess bactericidal properties. These chemicals were applied to pepper plants in a randomized block design. Four replicated plots were used, each of which contained 20 plants. Three gallons of spray per treatment were applied on April 5, 12, and 20 with a Model 335D three-gallon Hudson hand sprayer, and four gallons of spray per treatment were applied on April 28, May 11, 18, and 25, June 2, 9, 15, and 28, and July 5 with a Model 33-C 15-gallon John Bean Sprayer. These plants were inoculated with X. vesicatoria on May 11 with a three-gallon hand sprayer.

Disease ratings were made on July 8, by the method shown in Table II.

During the spring of 1962, 23 antibiotics and 99 chemicals were screened in vitro to determine if they possessed any inhibitory effect on X. vesicatoria by the filter paper disc-agar diffusion method.

Table I. Chemicals and concentration of each used in 1961 field tests

Chemical	Concentration of active material
	ppm
1. EP-166 (97% 9-) p-n-hexyloxyphenyl)-10-methyl-acridinum chloride)	400
2. Nabac 25 (25% 2,2' methylenebis (3,4,6-trichlorophenol)	1,000
3. Septigard 25 (10% alkyl tolyl methyl trimethyl ammonium chlorides)	1,000*
4. Preventol GD (96% dihyroxy-dichloro-diphenylmethane)	1,000

*On June 9 the concentration of Septigard was reduced to 500 ppm because of its phytotoxic effect on the plants.

Table II. Method of disease rating

Rating	Amount of infection
0	No infection
1	Trace of infection; up to 1/4 plants infected
2	1/4-3/4 of plants infected; no defoliation
3	3/4 to all plants infected with only a trace of defoliation
4	Every plant infected with little defoliation
5	Every plant infected and partially defoliated

A 48-hour culture of X. vesicatoria grown at room temperature in potato dextrose broth was mixed with potato dextrose agar which was prepared from the liquid of 200 grams of boiled potatoes, 17 grams of agar, and sufficient water to bring the volume up to one liter. Approximately 30 ml of the medium and bacteria were poured into each petri dish. Discs, 12.7 mm in diameter, made from Schleicher and Schull Analytical Filter Paper were soaked for an hour in the material to be tested. Each antibiotic and chemical was diluted to 500 ppm active material. Two petri dishes which contained three discs each were used to test each material in the screening process. Data representing inhibitory activity of the materials were taken after 36-40 hours at room temperature, which ranged from approximately 25° to 30°C. The diameters of the circles of inhibition less the diameter (12.7 mm) of the filter paper discs were the measurements recorded. Seven of the antibiotics and 52 of the chemicals that inhibited the growth of X. vesicatoria to varying degrees were then tested at a concentration of 100 ppm active material.

Eight of these materials which inhibited the growth of the organism to the greatest extent and which were reported to be the least phytotoxic were used in field tests. The materials and the concentrations at which they were applied to pepper plants in a randomized block design are given in Table III. Four replicated plots, each of which contained 20 plants, were used. Four gallons of spray were applied on May 11, 18, and 25 and June 4, 12, 20, and 26 with a Model 33-C 15-gallon John Bean Sprayer for all the treatments except streptomycin

Table III. Materials and concentration of each used in 1962 field tests

Material	Concentration of active material ppm
1. Neomycin sulfate	200
2. Streptomycin sulfate	200
3. Agri-mycin 17	200
4. DAC 649	200
5. Nurelle	300
6. WO 4778	4
7. Niagara 9130	200
8. Cupric Omadine	1,200
9. Cupric Omadine + 1,200 ppm lime	1,200
10. Control	

sulfate and neomycin sulfate which were applied with a Model 9B two-gallon Hudson hand sprayer after dark on the same dates. In case of treatments eight and nine, Omadine Mn salt was found to give a high degree of inhibition against X. vesicatoria in vitro; however, it was suggested by Olin Mathieson Chemical Corp. that cupric Omadine by itself and in combination with lime be tested in the field trials since the production of Omadine Mn salt had been terminated. A commercial preparation of spreader-sticker was applied with each of the treatments. These plants were inoculated with X. vesicatoria on May 18 with a two-gallon hand sprayer.

In 1961, commercial 8-8-8 fertilizer was applied to soil prior to transplanting bell pepper plants in four separate treatments of 1,000, 2,000, 4,000, and 6,000 pounds per acre. Three additional treatments were used in which 1,000, 2,000, and 3,000 pounds per acre of the same type fertilizer was applied to the soil prior to transplanting the plants to the field. Equal amounts of fertilizer were applied to the respective plots as side dressings seven weeks later. A randomized block design with four replications and 20 plants per replication was used for all treatments. These plants were inoculated with X. vesicatoria on May 11 with a three-gallon hand sprayer.

In 1961, at Ponchatoula, Louisiana, a total of 1,300 disease-free pepper plants were set in eight rows. One thousand pounds per acre of commercial 8-8-8 fertilizer was applied to four of the rows and

5,000 pounds of commercial 8-8-8 fertilizer to the other four rows prior to planting.

Results of the 1961 fertilizer test prompted an investigation to determine whether nitrogen, phosphorus, or potassium or a combination of these three elements was responsible for the increased resistance of bell peppers to bacterial leaf spot. In the 1962 field trials, 1,000 pounds per acre of commercial 8-8-8 fertilizer, applied in the row, was supplemented with additional amounts of fertilizer added as side dressings. The treatments in the randomized replicated block design were:

1. Control--which had only the 1,000 pounds per acre of 8-8-8 fertilizer applied in the row.

2. 1,000 pounds per acre of 8-8-8 fertilizer applied in the row side dressed with 480 pounds per acre of P (20% superphosphate)

3. 1,000 pounds per acre of 8-8-8 fertilizer applied in the row side dressed with 480 pounds per acre of K (60% potash)

4. 1,000 pounds per acre of 8-8-8 fertilizer applied in the row side dressed with 480 pounds per acre of N (ammonium nitrate)

5. 1,000 pounds per acre of 8-8-8 fertilizer applied in the row side dressed with 480 pounds per acre of each N, P, and K (8-8-8 fertilizer)

The plants were set on March 19 and the supplement fertilizers were added on May 11. These plants were inoculated with X. vesicatoria on May 18 with a two-gallon hand sprayer.

Laboratory studies were conducted with X. vesicatoria to see

if cupric Omadine and streptomycin sulfate were bactericidal or bacteriostatic. Filter paper discs, 12.7 mm in width, were impregnated with these two materials at the concentration of 100 ppm active material and placed on PDA plates seeded with the organism. After 36-40 hours incubation at room temperature, transfers were made from the zones of inhibition to potato dextrose broth. The cultures resulting from these transfers were used to seed other PDA plates. Cupric Omadine and streptomycin sulfate impregnated filter paper discs (100 ppm) then were placed on these plates to determine whether or not the isolates were resistant to cupric Omadine and streptomycin sulfate or whether or not the effect was only bacteriostatic.

EXPERIMENTAL RESULTS

Studies on the over-seasoning of X. vesicatoria

None of the 9,000 disease-free plants, set at a location near Hester, Louisiana in 1961, became infected with X. vesicatoria when transplanted to a field in which infected pepper plants had been grown the preceding year. However, the disease did appear in some commercial plantings which were approximately one-quarter of a mile away. The pepper plants in the experimental plot were checked for bacterial leaf spot every seven to ten days.

The disease was not found in the 1,300 disease-free plants set at the Ponchatoula location. Other commercial plantings in the immediate vicinity were not examined for infection.

No bacterial leaf spot appeared on 600 disease-free pepper plants transplanted to the Perkins Road Farm where pepper plants infected with X. vesicatoria had been grown the preceding year. These plants were observed daily for the appearance of bacterial leaf spot. However, 150 disease-free plants transplanted to soil virgin to peppers approximately 200 yards from the above planting and only 50 feet from peppers with bacterial leaf spot became infected following two weeks of heavy, wind-blown rain.

In the 1962 field plots located in St. James Parish, bacterial leaf spot was not found in the isolated plots at locations A, B, C,

and D. The disease had been reported on peppers at all these locations the preceding year. Bacterial leaf spot did develop in the pepper plants at location E near Hester, Louisiana. However, the disease was observed five days earlier in a commercial planting adjacent to this plot.

The 250 plants set at the Idlewild Experiment Station near Clinton, Louisiana in 1962, remained free of bacterial leaf spot throughout the season which indicated that the original plants grown in the coldframe were disease-free plants.

Disease-free pepper seed were planted in disease-infested soil in two flats on each of the following dates: December 14, January 17, February 16, March 16, April 28, and May 30. The soil used in this series of tests was prepared the previous July, at which time, infected pepper plants were chopped and mixed with the soil and placed in five-gallon crocks. The subsequent plants were watered in such a manner that soil was splashed on the leaves. These plants were maintained until September 1961, and during this period no bacterial leaf spot developed on any of the six separate plantings. In five separate attempts on January 26, February 16, April 10, May 19, and June 22 the bacterium was not isolated from this soil when the dilution plate method was employed.

In July 1961, ten, five-gallon crocks were filled with field soil from the Perkins Road Farm, and this soil was infested with diseased pepper plants and a culture of the bacterium. The following April, disease-free plants were transplanted to these five-gallon crocks.

When the plants were watered, soil from the medium was always splashed on the foliage. In addition, a slurry of this infested soil was poured over the surface of the leaves approximately every two weeks. The plants were maintained until September and, during this period, none of the plants became infected with X. vesicatoria. The bacterium was not recovered from this soil in three separate attempts on December 20, February 1, and March 26, when the soil dilution plate method was used.

Laboratory antibiotic and chemical screening test

During the spring of 1962, 23 antibiotics and 99 chemicals were screened in the laboratory to determine if they exhibited any inhibitory effect on X. vesicatoria. Seven of the antibiotics and 52 of the chemicals inhibited the organism to varying degrees when they were tested at 500 ppm active material by the filter paper disc-agar diffusion method. The materials that showed any degree of inhibition against X. vesicatoria at the above concentration were then tested by the same procedure at 100 ppm. In this instance some inhibition of X. vesicatoria was shown by five antibiotics and 40 chemicals. The antibiotics, Agri-mycin 17, neomycin sulfate, and streptomycin sulfate, and the chemicals, DAC 649, Nurelle, Niagara 9130, EP-166, EP-166b, Omadine Mn salt, and WO 4778, inhibited the organism to the greatest extent both at 500 and 100 ppm (Table IV).

Table IV. The effect of various antibiotics and chemicals on X. vesicatoria in vitro.

Chemical company	Material	Concentration 500 ppm	Concentration 100 ppm
		Inhibition in mm	
ANTIBIOTICS			
Chas. Pfizer & Co., Inc.	Agri-mycin 17 (21.3% streptomycin sulfate)	22.3	13.8
Chas. Pfizer & Co., Inc.	Anisomycin	0.0	-
Chas. Pfizer & Co., Inc.	Oligomycin	0.0	-
Commercial Solvents Corp.	Fradicin (90%)	0.0	-
Olin Mathieson Chem. Corp.	Mycostatin 1666 (10%)	0.0	-
Olin Mathieson Chem. Corp.	Mycostatin (50%)	0.0	-
S. B. Penick & Co.	Bacitracin	0.0	-
S. B. Penick & Co.	Candicidin	0.0	-
S. B. Penick & Co.	Gramicidin	0.0	-
S. B. Penick & Co.	Neomycin sulfate	12.3	9.2
S. B. Penick & Co.	Penitracin	T**	0.0
S. B. Penick & Co.	Tyrocidine hydrochloride	0.0	-
S. B. Penick & Co.	Tyrothricin	T	T
S. B. Penick & Co.	517 RTF	0.0	-
The Upjohn Co.	Acti-dione 11584-4	0.0	-
The Upjohn Co.	Bactitracin 2504-H	0.0	-
The Upjohn Co.	Endomycin 9922-11	0.0	-
The Upjohn Co.	Filipin 4370 GBW 88	0.0	-
The Upjohn Co.	Griseofulvin (50%)	0.0	-
The Upjohn Co.	Penicillin G Potassium 2771-4	0.0	-

Table IV. Continued

Chemical company	Material	Concentration 500 ppm	100 ppm
		Inhibition in mm	
ANTIBIOTICS (Cont'd)			
The Upjohn Co.	Polymixin 115 MEB 2	5.0	0.0
The Upjohn Co.	Streptomycin Sulfate powder 3534-F	20.0	15.8
The Upjohn Co.	Tetracycline USP Base 3335-P	11.3	10.1
CHEMICALS			
Allied Chem.	Cpd. 2266 (Experimental)	0.0	-
American Cyanamid Co.	28720 (25%) (Experimental)	T	0.0
Antara Chem.	Preventol GD (96% Dihydroxy-dichlorodiphenylmethane)	5.0	0.0
Carbon & Carbon Chem. Co.	Crag Potato Fungicide (Cu, Zn, Cr)	0.0	-
Carbon & Carbon Chem. Co.	224 (Experimental)	9.6	6.1
Carbon & Carbon Chem. Co.	6970 (Experimental)	0.0	-
Chas. Pfizer & Co., Inc.	Sorbistat ($C_6H_{14}O_6$)	0.0	-
Chemagro Corp.	Bayer 32394 (25%) (Experimental)	7.3	6.6
Chemagro Corp.	2635 (70%) (Experimental)	3.0	0.0
Chemagro Corp.	2635 (Experimental)	10.6	3.5
Chipman Chem. Co., Inc.	(Cadmium dithio carbamate)	0.0	-
Chipman Chem. Co., Inc.	Merbam 10 (Experimental)	T	0.0

Table IV. Continued

Chemical company	Material	Concentration 500 ppm	100 ppm
		Inhibition in mm	
CHEMICALS (Cont'd)			
Diamond Alkali Co.	DAC 649 (75% 3,3,4,4-tetrachlorotetrahydrothiophene-1,1-dioxide)	C***	18.3
Dow Chem. Co.	Dowicide A (97%) (Experimental)	0.0	-
Dow Chem. Co.	Harven (10%) (Experimental)	0.0	-
Dow Chem. Co.	Morraen (27.4% Na 2,4,5-trichlorophenate)	7.6	0.0
Dow Chem. Co.	Nellite Formulation M-2010 (Exp.)	0.0	-
Dow Chem. Co.	Nurelle (17.3% 2,4,5-trichlorophenol)	20.1	4.6
Dow Chem. Co.	Torsite (Experimental)	1.3	0.0
Dow Chem. Co.	Zectean (25%) (Experimental)	0.0	-
E. I. duPont de Nemours & Co.	Manzate-Maneb (80% Manganese ethylenebisdithiocarbamate)	12.8*	4.6*
E. I. duPont de Nemours & Co.	Thylate (65% Bis (dimethylthiocarbamyl) disulfide)	25.0*	25.0*
E. I. duPont de Nemours & Co.	Zerlate (67% Zinc dimethyldithiocarbamate)	15.8*	10.1*
Eli Lilly & Co.	C-275 (10%) (Experimental)	0.0	-
Eastman Kodak Co.	(8-Hydroxyguinoline sulfate)	15.5	7.3
Food Mach. & Chem. Corp., Niagara Chem. Div.	ME 5356 (Experimental)	0.0	-
Food Mach. & Chem. Corp., Niagara Chem. Div.	Nia 5619 (75%) (Experimental)	T	0.0

Table IV. Continued

Chemical company	Material	Concentration 500 ppm	100 ppm
		Inhibition in mm	
CHEMICALS (Cont'd)			
Food Mach. & Chem. Corp., Niagara Chem. Div.	Nia 6636 (Experimental)	0.0	-
Food Mach. & Chem. Corp., Niagara Chem. Div.	5619 (50%) (Experimental)	8.8	2.3
Food Mach. & Chem. Corp., Niagara Chem. Div.	5769 (50%) (Experimental)	21.1	2.8
Food Mach. & Chem. Corp., Niagara Chem. Div.	9102 (80%) (Experimental)	3.1	T
Food Mach. & Chem. Corp., Niagara Chem. Div.	9130 (75%) (Experimental)	26.1	9.3
Foote Mineral Co.	(Lithium hydroxide monohydrate)	14.1	12.3
Mallinckrodt	Calogreen (mercurous chloride)	12.1	7.6
Merck & Co., Inc.	(HMF Acetate bisulfite)	0.0	-
Merck & Co., Inc.	HMF Propionate (Experimental)	0.0	-
Merck & Co., Inc.	Methoxy 59RTS1348 (Experimental)	0.0	-
Merck & Co., Inc.	Propionate 59RTS1345 (Experimental)	0.0	-
Merck, Sharp & Dohme Res. Lab.	(Dimethylformamide)	0.0	-
Metalsalts Corp.	(8-Hydroxy-7-Iodoquinoline-5-sulphonic acid)	3.3	0.0
Metalsalts Corp.	(8-Hydroxyquinoline-5-sulphonic acid)	0.0	-

Table IV. Continued

Chemical company	Material	Concentration 500 ppm	100 ppm
		Inhibition in mm	
CHEMICALS (Cont'd)			
Monsanto Chem. Co.	CP 19210 (Experimental)	0.0	-
Monsanto Chem. Co.	CP 40334 (Experimental)	0.0	-
Monsanto Chem. Co.	CP 40135 (Experimental)	10.5	5.8
Monsanto Chem. Co.	CP 40142 (Experimental)	0.0	-
Morton Chem. Co.	EP 166 (97% 9-(p-n-hexyloxyphenyl)-10-methyl-acridinum chloride)	21.3	22.6
Morton Chem. Co.	EP 166B (Experimental)	18.8	20.3
Morton Chem. Co.	EP-177D (Experimental)	0.0	-
Morton Chem. Co.	EP-177WP (75% active) (Experimental)	2.0	2.3
Nationwide Chem. Co.	Nabac-25 (25% 2,-2-Methylebis 3,4,6-trichlorophenol)	8.6	1.3
Nationwide Chem. Co.	5-10 Nabac (1.25% 2,-2-Methylenebis (3,4,6-trichlorophenol) Captan dust (5% N-trichloromethylthio)-4 cyclohexene-1,2-dicarboximide)	4.0	T
Olin Mathieson Chem. Corp.	G 1143 (25%) (Experimental)	6.3	0.0
Olin Mathieson Chem. Corp.	Omadine Mn salt (50% 2-pyridimethione 1-oxide, manganese salt)	35.5	11.3
Olin Mathieson Chem. Corp.	Spergon (2,3,5,6-Tetrachloro-1,4-benzoquinone)	0.0	-

Table IV. Continued

Chemical company	Material	Concentration 500 ppm	Concentration 100 ppm
		Inhibition in mm	
CHEMICALS (Cont'd)			
Onyx Oil & Chem. Co.	Ammonyx 78 (Experimental)	2.1	1.6
Onyx Oil & Chem. Co.	BTC (50%) (Experimental)	2.5	2.3
Onyx Oil & Chem. Co.	BTC 927 (Experimental)	1.5	1.6
Onyx Oil & Chem. Co.	BTC 1100 (Experimental)	T	T
Onyx Oil & Chem. Co.	BTC 2125 (50%) (Experimental)	T	T
Onyx Oil & Chem. Co.	Isothan Q15 (20% laurylisoquinolinium bromide)	2.1	1.3
Onyx Oil & Chem. Co.	Isothan Q75 (75% laurylisoquinolinium bromide)	2.8	T
Onyx Oil & Chem. Co.	Onyxide (75% alkenyldimethylethyl-ammonium bromide)	0.0	-
Onyx Oil & Chem. Co.	Tetrosan 3,4 D (alkyldimethyl-3,4-dichlorobenzylammonium chloride)	2.5	1.3
Panogen Inc.	WO 4778 (8.5% Methylmercury hydroxide)	C	37.1
Pennsalt Chem. Corp.	NP-1711 (50%) (Experimental)	0.0	-
Pennsalt Chem. Corp.	NP-1772 (Experimental)	0.0	-
Pennsalt Chem. Corp.	Thiram (75% Bis(dimethylthiocarbamoyl) disulfide)	20.1*	22.3*
Pennsalt Chem. Corp.	TD-211 (50%) (Experimental)	9.1	2.1
Pennsalt Chem. Corp.	TD-212 (Experimental)	8.6	3.6
Pennsalt Chem. Corp.	TD-213 (50%) (Experimental)	11.6	3.3
Pennsalt Chem. Corp.	TD-226 (Experimental)	0.0	-

Table IV. Continued

Chemical company	Material	Concentration 500 ppm	100 ppm
		Inhibition in mm	
CHEMICALS (Cont'd)			
Processing Laboratories	Phenamin (Alkyl N-propyldiamine)	3.6	T
Rohm & Haas	Dithane M-45 (Experimental)	8.6	2.3
R. T. Vanderbilt Co.	Vancide 51 (30% N-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide)	0.0	-
Shell Development Co.	SD 4741 (Experimental)	0.0	-
Shell Development Co.	SD 5529 (50%) (Experimental)	0.0	-
Shell Development Co.	SD 5529 (Experimental)	0.0	-
Stauffer Chem. Co.	Captan (50% N-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide)	3.0	1.3
Stauffer Chem. Co.	Phaltan (50% N-(tri-chloromethylthio) phthalimide)	0.0	-
Tennessee Corp.	TC 11 (Experimental)	0.0	-
Tennessee Corp.	TC 22 (Experimental)	0.0	-
Tennessee Corp.	TC 50 (Experimental)	0.0	-
Tennessee Corp.	TC 55 (Experimental)	0.0	-
Tennessee Corp.	Tennan (Experimental)	T	0.0

Table IV. Continued

Chemical company	Material	Concentration 500 ppm	100 ppm
		Inhibition in mm	
CHEMICALS (Cont'd)			
Thompson-Hayward Co.	Septigard 25 (10% Methyldodecylbenzyl trimethyl ammonium chloride)	1.3	T
The Upjohn Co.	Acti-dione acetate (Experimental)	0.0	-
The Upjohn Co.	Acti-dione acetoacetate (Experimental)	0.0	-
The Upjohn Co.	Acti-dione oxime (Experimental)	0.0	-
The Upjohn Co.	Botran (50%) (Experimental)	0.0	-
The Upjohn Co.	Cycloheximide thiosemicarbazone 3544 (Experimental)	0.0	-
The Upjohn Co.	U-2069 (50%) (Experimental)	0.0	-
U.S. Rubber Co., Naugatuck Chem. Div.	B 165 (Experimental)	0.0	-
U.S. Rubber Co., Naugatuck Chem. Div.	B 512 (Experimental)	0.0	-
U.S. Rubber Co., Naugatuck Chem. Div.	B 577 (Experimental)	4.0	0.0
U.S. Rubber Co., Naugatuck Chem. Div.	B 720 (75%) (Experimental)	0.0	-
U.S. Rubber Co., Naugatuck Chem. Div.	D 2002 (Experimental)	3.5	0.0
U.S. Rubber Co., Naugatuck Chem. Div.	Phygon (2,3-dichloro-1,-4 napthoquinone)	0.0	-
U.S. Rubber Co., Naugatuck Chem. Div.	06K (Experimental)	0.0	-
U.S. Rubber Co., Naugatuck Chem. Div.	36L (Experimental)	4.0	9.2

*Initial inhibition with zone indistinct after 48 hours.
**Trace of inhibition.
***Complete inhibition.

Field tests with bactericidal sprays

In a preliminary field test, before the laboratory screening method was employed, four chemicals were used in a randomized block design to evaluate them for bacterial leaf spot control. None of these four chemicals appeared to be effective in the control of the disease. On July 8 disease ratings, which are described in Table II, were made. These data are shown in Table V.

Table V. The disease ratings of pepper plants sprayed with bactericides in 1961 field tests

Chemical	Disease ratings on July 8*
EP-166	5.00
Nabac 25	5.00
Septigard 25	4.75
Preventol GD	5.00
Control	5.00

*Each rating represents an average of the four replications per treatment.

During 1962 a randomized block design with four replications containing 20 plants each was employed to test the effectiveness of neomycin sulfate, streptomycin sulfate, Agri-mycin 17, DAC 649, WO 4778, Niagara 9130, cupric Omadine, and cupric Omadine in combination with lime as control measures for bacterial leaf spot. These materials were applied with a 15-gallon sprayer on a seven-day schedule when weather

conditions permitted. On June 22 the disease ratings for neomycin sulfate, streptomycin sulfate, and cupric Omadine with lime were significantly lower than the control rating. However, dry weather prevailed during this period and the plots were watered each week with an overhead irrigation system. Between June 22 and July 1 more than four inches of rain fell in the experimental area, and disease ratings were made again on July 4. Analysis of these data failed to show a significant difference between any of the treatments (Table VI).

Table VI. The disease ratings on June 22 and July 4 of pepper plants sprayed with bactericides in 1962 field tests

Material	Disease rating	
	June 22*	July 4*
1. Neomycin sulfate	1.75	5.00
2. Streptomycin sulfate	2.25	4.50
3. Agri-mycin 17	2.50	4.75
4. DAC 649	4.00	4.50
5. Nurelle	4.50	5.00
6. WO 4778	2.75	5.00
7. Niagara 9130	2.75	4.75
8. Cupric Omadine salt	2.75	4.75
9. Cupric Omadine salt + lime	2.00	4.75
10. Control	3.75	4.75

*Each rating represents an average of the four replications per treatment.

L.S.D. 5% = .85
L.S.D. 1% = 1.14

Relation of fertilizer to disease resistance

Because high rates of fertilizer were reported to control bacterial leaf spot (38, 39), experiments were designed to study the relationship of the application of various rates of fertilizers to disease resistance and fruit production. The recommended rates of fertilizer per acre are 800 to 1,500 pounds of 5-10-5, 5-10-10 or equivalent per acre, plus 16 pounds of readily available nitrogen as a side dressing. In 1961, four separate treatments of 1,000, 2,000, 4,000, and 6,000 pounds per acre of commercial 8-8-8 fertilizer were applied to the soil prior to transplanting bell pepper plants in a randomized block design. Three additional treatments were used in which 1,000, 2,000, and 3,000 pounds per acre, respectively, of commercial 8-8-8 fertilizer were applied to the soil prior to planting. After seven weeks these plants were side dressed with commercial 8-8-8 fertilizer which was applied at the same rates used at the start of the test. Results of these tests indicated that bacterial leaf spot was significantly less severe on plants that were grown in soil with the two higher rates of fertilization. However, plants that were grown on plots that had the higher rates of fertilizer, produced significantly lower numbers of marketable peppers (Figure 1). Comparable results were obtained when the fertilizer was applied partly as a side dressing (Figure 2).

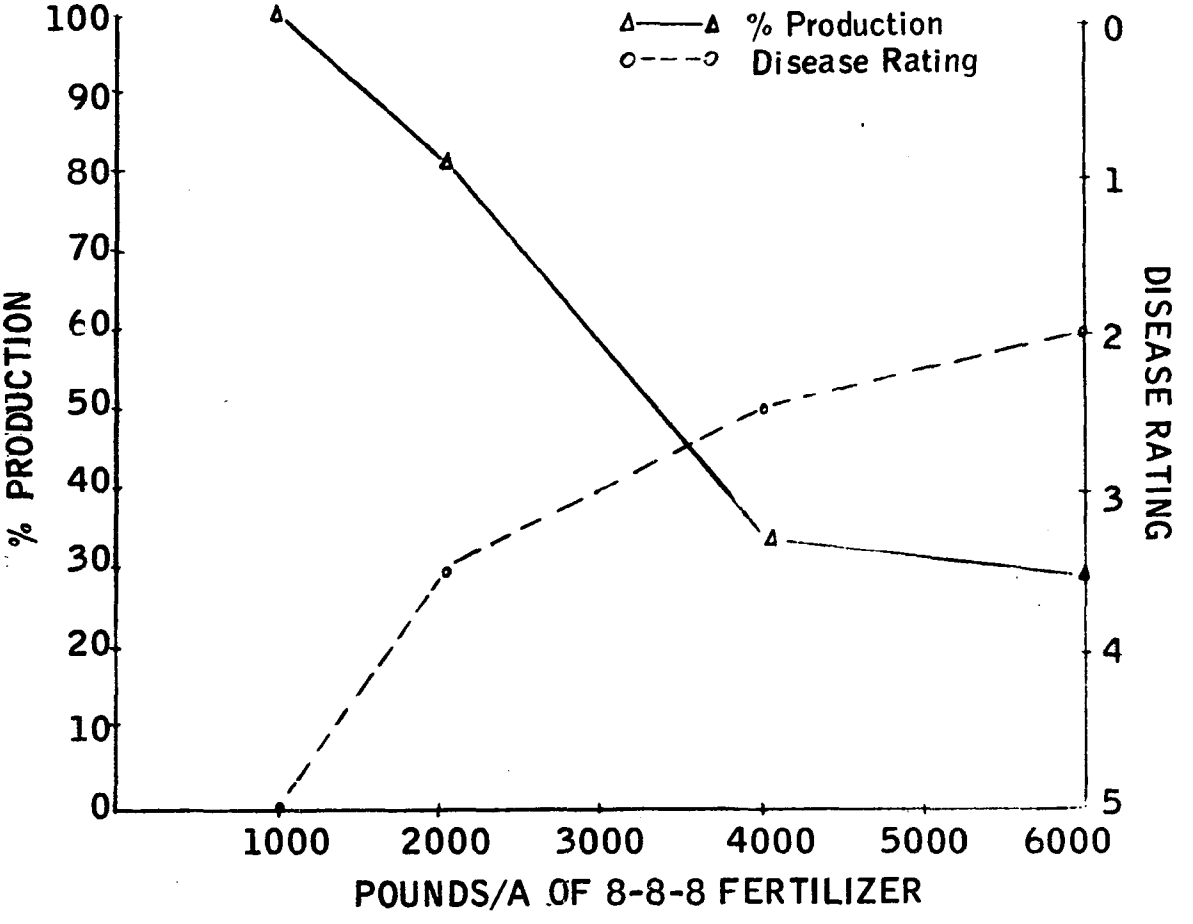

Figure 1. The control of bacterial leaf spot and the percentage of marketable peppers were inversely proportional to each other when high rates of commercial 8-8-8 fertilizer were applied in the row only.

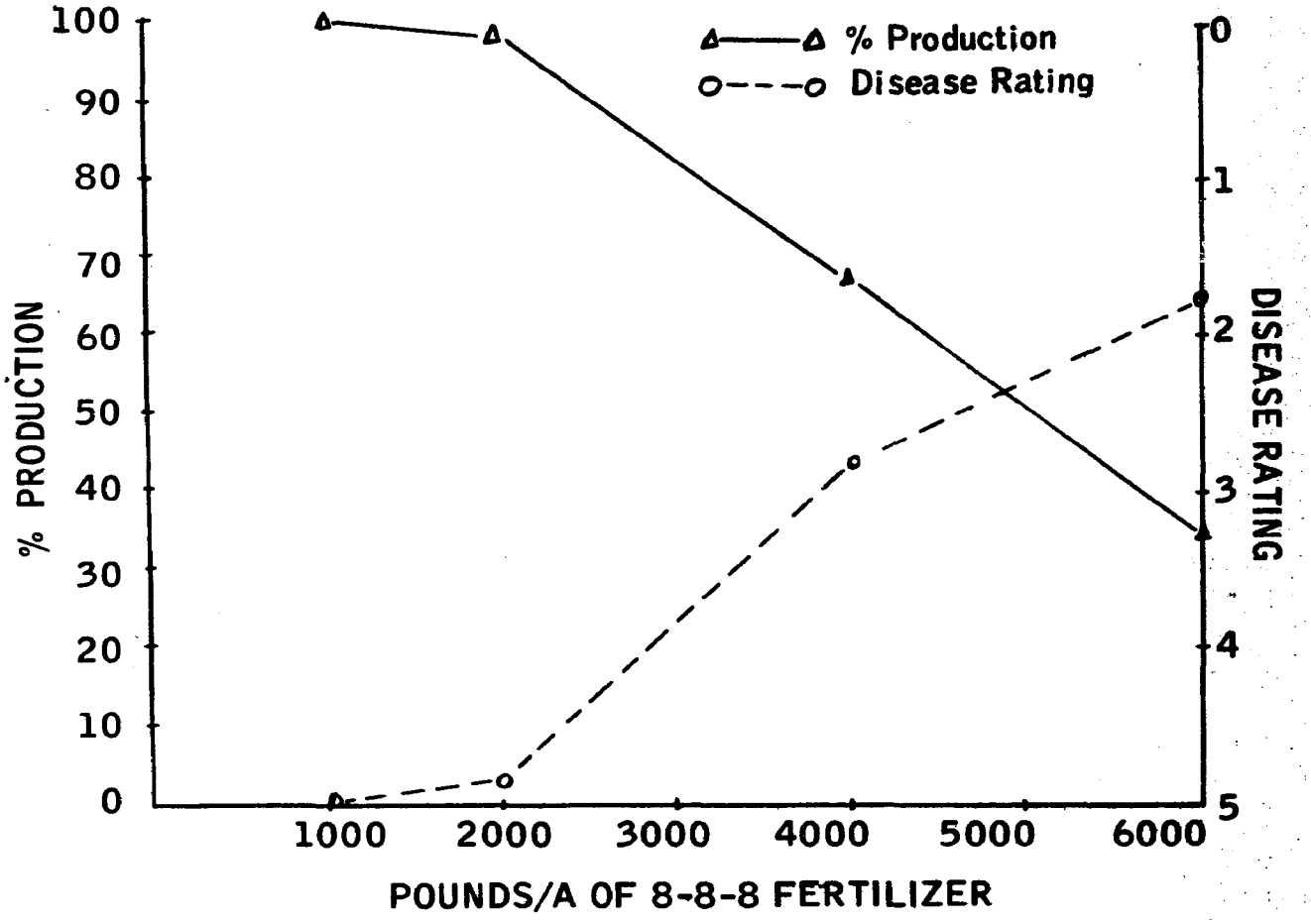

Figure 2. The control of bacterial leaf spot and the percentage of marketable peppers were inversely proportional to each other when high rates of commercial 8-8-8 fertilizer were applied one-half in the row and one-half as a side dressing.

No bacterial leaf spot developed in the fertilizer field test plot near Ponchatoula in 1961; however, the numbers of marketable fruit were much lower in plots treated with 5,000 pounds per acre of commercial 8-8-8 fertilizer than in those from the plots treated with 1,000 pounds per acre of the same material.

Since bacterial leaf spot was reduced significantly with high rates of a complete fertilizer in 1961, an experiment was designed in 1962 to study the effect of additional amounts of N, P, and K, respectively, and to ascertain the relation of these additives to disease resistance and the production of marketable peppers. Results of this test showed that when plants were grown in soil which had 1,000 pounds per acre of commercial 8-8-8 fertilizer applied in the row and an additional 480 pounds per acre of nitrogen added as a side dressing the incidence of bacterial leaf spot was significantly reduced. Under these same conditions the pounds of marketable peppers were significantly reduced (Figure 3).

The resistance of X. vesicatoria to cupric Omadine and streptomycin sulfate in vitro

Distinct zones of inhibition, which were due to the presence of filter paper discs impregnated with cupric Omadine and streptomycin sulfate at 100 ppm, were observed on PDA seeded with X. vesicatoria. Transfers from these inhibition zones placed in PD broth, gave abundant growth of the organism in each case. Filter paper discs impregnated

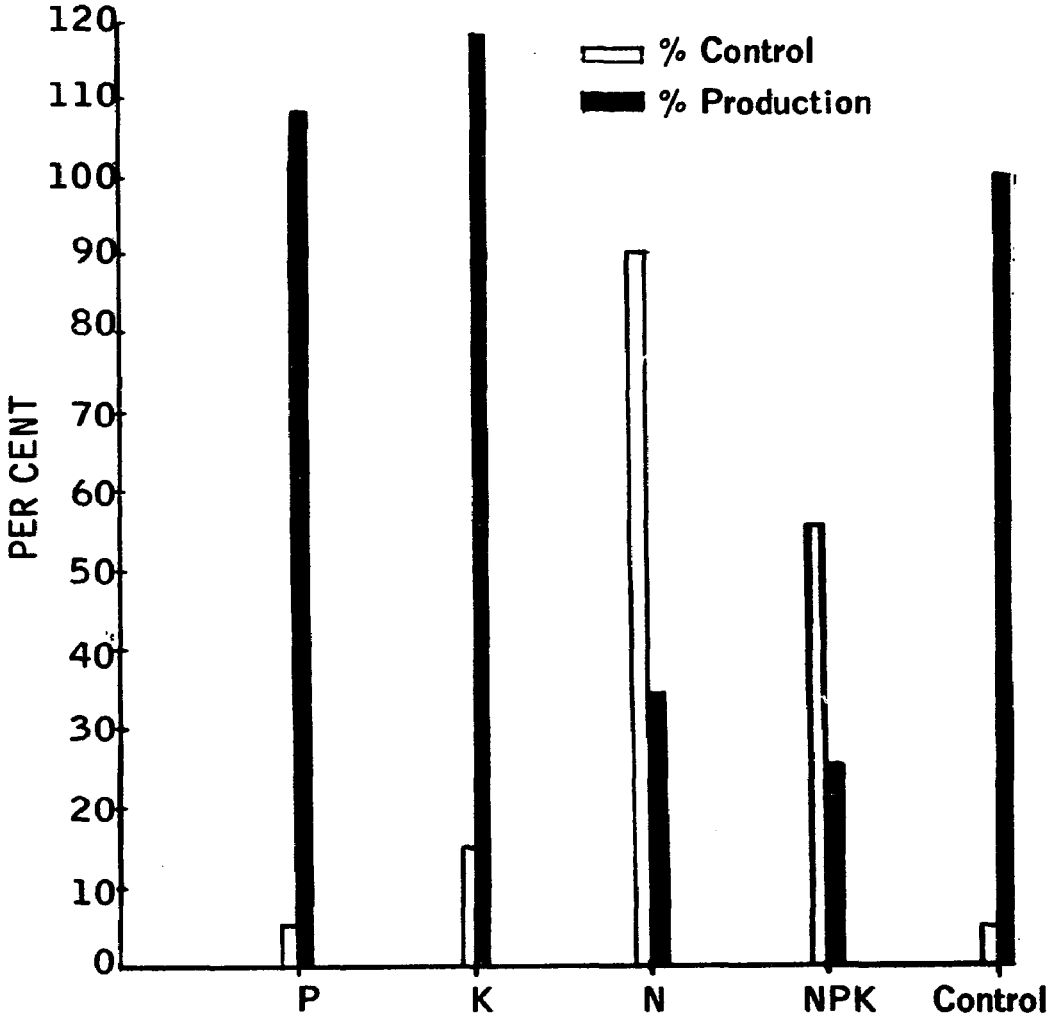

Figure 3. The control of bacterial leaf spot with high rates of commercial 8-8-8 fertilizer and high rates of nitrogen and the reduction of marketable peppers with the same treatment.

with cupric Omadine and streptomycin sulfate were placed on PDA which had been inoculated with the respective broth cultures obtained from the inhibition zones. Neither material inhibited the growth of these isolates.

DISCUSSION

Studies on the over-seasoning of X. vesicatoria have indicated that this organism does not live from one growing season to another in Louisiana under the conditions tested. Two lines of evidence supported this supposition. First, the disease was not observed at six isolated locations where disease-free plants were transplanted to soil in which peppers infected with X. vesicatoria were grown the preceding year. Secondly, numerous attempts to isolate the organism from artificially infested soil five to nine months after infestation were negative.

During the spring of 1962, 23 antibiotics and 99 chemicals were tested in vitro to determine their inhibitory effect against X. vesicatoria. Seven of these antibiotics and 52 of the chemicals tested at 500 and 100 ppm active material inhibited the organism in degrees varying from only a trace to complete inhibition. Maneb, Thiram, and Ziram formed initial inhibition zones which were overgrown after 48 hours. The indications were that the chemicals were altered in a few hours so that they were bacteriostatic only.

In a preliminary field test in 1961, before the laboratory screening tests were employed, four chemicals--EP-166, Nabac 25, Septigard 25, and Preventol GD--were applied weekly to pepper plants in a randomized field plot with four replications. Disease ratings of the amount of

infection present in these plants showed that the four materials tested were completely ineffective in controlling bacterial leaf spot.

Because neomycin sulfate, streptomycin sulfate, Agri-mycin 17, DAC 649, Nurelle, WO 4778, Niagara 9130, and cupric Omadine showed the greatest amount of inhibition against X. vesicatoria in vitro at 500 and 100 ppm active material they were tested in a randomized field plot with four replications. Cupric Omadine was tested both alone and in combination with equal parts of lime. Since there was very little rainfall before June 22, 1962, the plots were watered with an overhead irrigation system. Disease ratings made on June 22 were significantly lower than the control rating for neomycin sulfate, streptomycin sulfate, and cupric Omadine with lime. The difference in disease rating between cupric Omadine alone and in combination with equal parts of lime was not significant but approached significance. DAC 649 and Nurelle were rated higher than the control but not significantly higher. Between June 22 and July 1 more than four inches of rain fell on these plots making conditions very favorable for the development of bacterial leaf spot. By July 4 there were no significant differences between any of the treatments and the control.

Taylor (38) and Taylor and Dobson (39) reported that high rates of fertilizer controlled bacterial leaf spot. In order to determine the validity of these reports, experiments were designed to study this control measure and its effect on fruit production. If this method of control was effective and fruit production was not affected, growers

would certainly not hesitate to increase their rates of fertilization. In 1961 commercial 8-8-8 fertilizer at 4,000 and 6,000 pounds per acre significantly reduced the amount of bacterial leaf spot infection. However, these rates of fertilization significantly reduced the pounds of marketable fruit.

It was of interest then to determine which major fertilizer element was associated with disease control and how it affected pepper yields. One thousand pounds per acre of commercial 8-8-8 fertilizer were applied in the row. Additional amounts of fertilizer were supplied as treatments in a randomized block design. These treatments included the following: 1) 480 lbs/A of P, 2) 480 lbs/A of K, 3) 480 lbs/A of N, and 4) 480 lbs/A of each N, P, and K. Results indicated that the high rate of N was associated with the disease resistance. However, as in the previous test, a significant reduction in the disease was obtained, but, at the same time, a significant reduction in the pounds of marketable fruit occurred. It was concluded that increased rates of nitrogen were associated with both increased resistance to bacterial leaf spot and to the small numbers of marketable peppers produced. Obviously this method of control can not be used economically. Pepper plants grown in soil treated with increased rates of a complete fertilizer or increased rates of nitrogen alone developed bunchy growth with leaves smaller than those of the control. More fruit were produced with the increased fertilizer, but the majority failed to reach a marketable size (Plate 5).

Many of the fruit were produced terminally rather than axillary as in normal fruit production; thus, they were subjected to sunscald making them unmarketable (Plate 4).

Contrary to reports by Crossan and Krupka (10) and Krupka and Crossan (25) that streptomycin had a bacteriostatic effect on X. vesicatoria, results of these studies indicated that resistant strains of the organism were, in effect, being selected. This statement is based on the fact that, when the organism was recovered from zones of inhibition and grown in PD broth and transfers made to PDA on which filter paper discs impregnated with streptomycin sulfate were placed, no inhibition resulted. This indicated that the isolations were resistant to streptomycin.

SUMMARY

The objectives of these investigations were to determine whether or not X. vesicatoria, the causal organism of bacterial leaf spot of bell peppers, was capable of over-seasoning under Louisiana field conditions, to find any economically available antibiotic or chemical that would control the disease, to study the effect of high fertilizer rates on fruit production, and to ascertain which element in commercial fertilizer was responsible for the resistance.

The following results indicated that X. vesicatoria is not capable of over-seasoning in Louisiana under the conditions tested:

1. Disease-free plants set at a location near Hester and at the Perkins Road Farm in 1961, in areas where diseased plants had been grown the preceding year, failed to develop bacterial leaf spot.
2. Disease-free plants set near Ponchatoula in 1961 failed to develop bacterial leaf spot when grown in a field where many diseased plants had been observed in 1959.
3. Disease-free plants were set at isolated locations A, B, C, and D in St. James Parish in 1962. Similar plants were set at location E which was next to a commercial planting.
   a. Although diseased plants had been grown at locations A, B, C, and D the preceding year, no bacterial leaf spot developed in these plots.

b. The disease-free plants at location E became diseased. However, the disease was observed five days earlier in commercial plantings.

4. Two hundred and fifty disease-free plants set at the Idlewild Experiment Station in 1962 remained healthy throughout the growing season.

5. In eight separate attempts during 1961-62 the bacterium was not isolated from soil infested five to nine months earlier.

6. Disease-free plants set in flats on December 14, January 17, February 16, March 16, April 28, and May 30 in soil infested with diseased plants the previous July (1960) failed to become infected.

7. Disease-free plants set in five-gallon crocks which contained infected plants and a culture of the bacterium which was placed there nine months earlier failed to become infected although a slurry of the infested soil directly from these crocks was spread over the plants approximately every two weeks.

In a field test in 1961, EP-166, Nabac 25, Septigard 25 and Preventol GD failed to control bacterial leaf spot.

Of the 23 antibiotics and 99 chemicals tested in the laboratory by the filter paper disc-agar diffusion method, seven antibiotics and 52 chemicals showed some inhibition of X. vesicatoria when tested at 500 ppm active material. At 100 ppm active material, five antibiotics

and 40 chemicals inhibited the growth of the organism to varying degrees. When neomycin sulfate, streptomycin sulfate, and cupric Omadine with lime were tested in the field, each appeared to control the disease satisfactorily; however, when environmental conditions became extremely favorable for disease development, these materials failed to control the disease.

Four and six thousand pounds per acre of commercial 8-8-8 fertilizer which was applied in the row controlled bacterial leaf spot; however, the quantity and quality of marketable fruit was significantly reduced at these rates of fertilization.

High rates of nitrogen controlled bacterial leaf spot but significantly reduced the amount of marketable fruit.

In laboratory tests, strains of X. vesicatoria resistant to streptomycin sulfate and cupric Omadine were isolated from zones of inhibition exhibited by these two materials.

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Plate 1. Bacterial leaf spot on bell pepper leaves caused by X. vesicatoria.

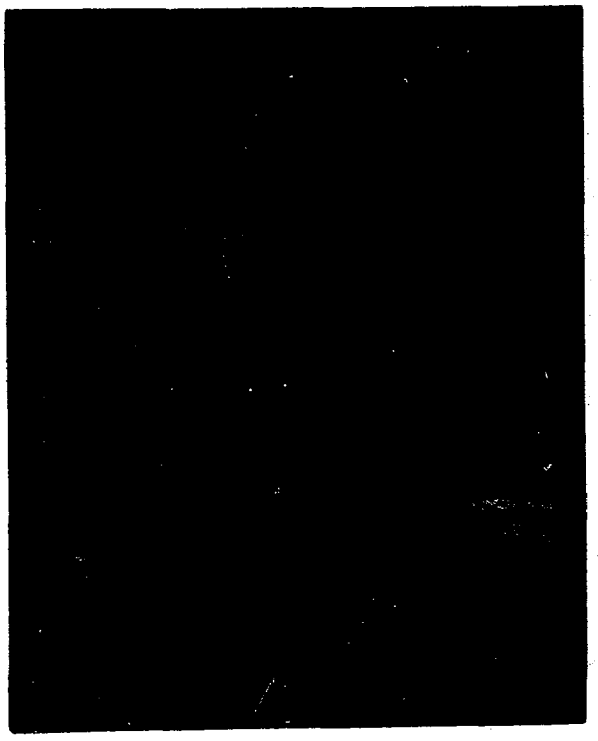

Plate 2. Disease-free plants remained healthy when they were set in soil which was infested nine months previously with infected plant material and a culture of X. vesicatoria.

Plate 3. A control plant which had 1,000 pounds per acre of commercial 8-8-8 fertilizer applied in the row. Note the defoliation.

Plate 4. A plant with 1,000 pounds per acre of commercial 8-8-8 fertilizer applied in the row and 480 pounds per acre of nitrogen applied as a side dressing. Note the compact foliage with small fruit produced on the terminal branches.

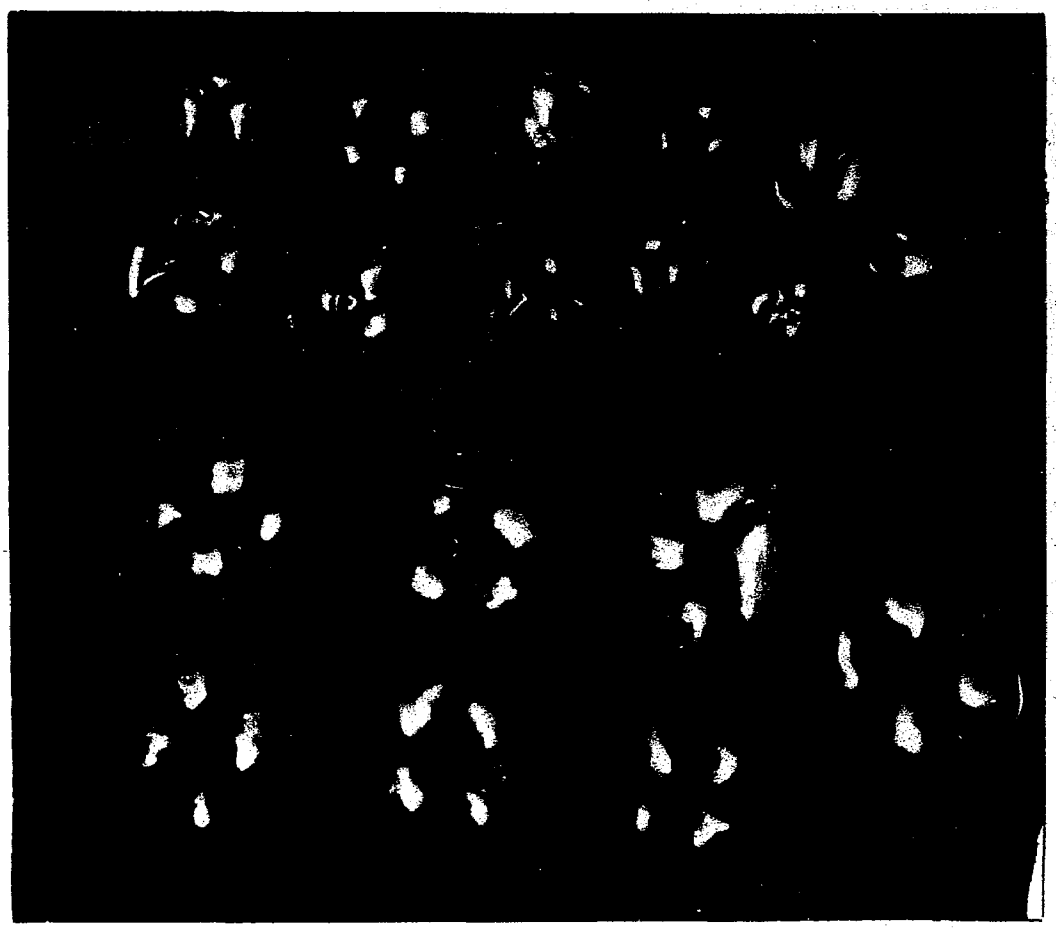

Plate 5. Above: Peppers from a plant grown in soil with high nitrogen fertilization.

Below: Peppers from a plant grown in soil with 1,000 pounds per acre of commercial 8-8-8 fertilizer.

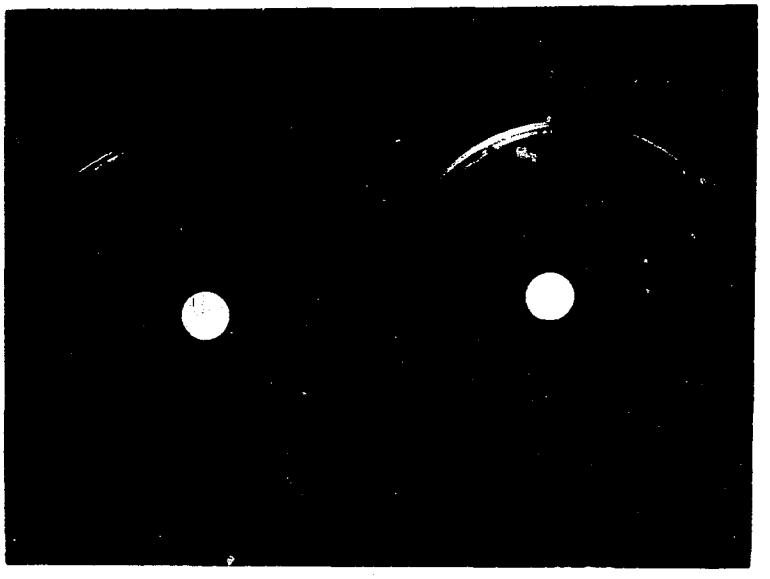

Plate 6. Inhibition of X. vesicatoria with streptomycin sulfate at 500 and 100 ppm, respectively.

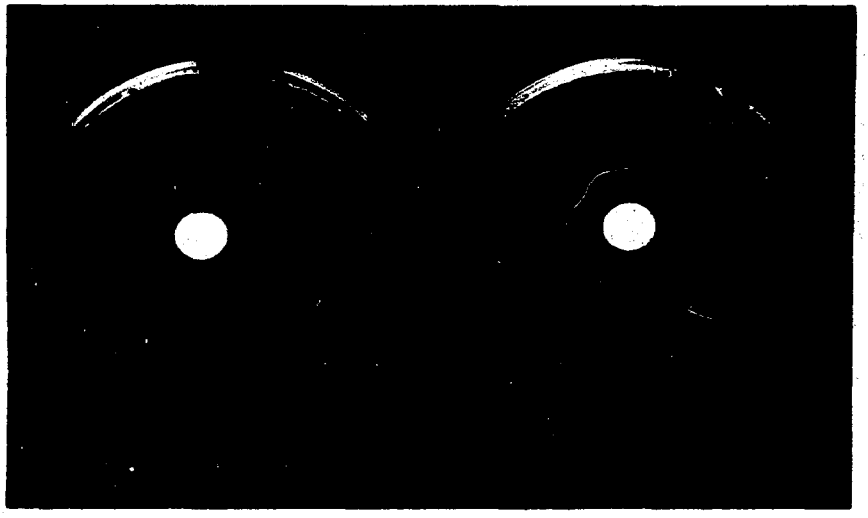

Plate 7. Resistance of X. vesicatoria to streptomycin sulfate. The culture on the right was obtained by making a transfer from an inhibition zone such as the one on the left. Both of the discs were soaked in 100 ppm streptomycin sulfate.

VITA

Jeff Harlin Jenkins was born March 8, 1937, in Monroe County, Kentucky. He finished Gamaliel High School in May 1955 and enrolled at Western Kentucky State College in September 1955. He completed the requirements for the Bachelor of Science degree in January 1959. He married the former Miss Martha Ann Combs on January 25, 1959, and they are now the proud parents of two children, Ann Beth, born January 5, 1962 and James Jeffrey, born April 26, 1963. He began graduate study in the Department of Botany and Plant Pathology at Louisiana State University in February 1959 and received the Master of Science degree in January 1961. He is at present a candidate for the degree of Doctor of Philosophy in August 1963.

EXAMINATION AND THESIS REPORT

Candidate: Jeff Harlin Jenkins

Major Field: Plant Pathology

Title of Thesis: Studies on Bacterial Leaf Spot of Bell Pepper and the Causal Organism Xanthomonas Vesicatoria (Doidge) Dowson

Approved:

N L Horn

Major Professor and Chairman

Max Goodrich

Dean of the Graduate School

EXAMINING COMMITTEE:

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Date of Examination:

June 21, 1963